$\nu_\mu \rightarrow \nu_e$ BIGGEST SECRETS FINALLY REVEALED
ACT 1: THE **N**EAR **D**ETECTOR **O**N THE **S**URFACE

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- There is now very strong evidence that neutrinos oscillate and neutrino mass and mixing provides a simple and powerful explanation of the world's data on neutrino oscillation.

- NOvA is an experiment intended to study neutrino and antineutrino oscillations in detail:

  - The transition: $\nu_\mu \rightarrow \nu_e$. MINOS and T2K now strongly indicate it occurs. The goal is to measure the parameter: θ_{13}.
  - The *Mass Hierarchy* is not fully understood, *i.e.* which neutrino is the lightest? Which is the heaviest?
  - There seems to be more matter than antimatter in the Universe. Why? Is the *CP* violating phase, δ, non − zero? *i.e.* is there *CP* violation in the leptonic sector?
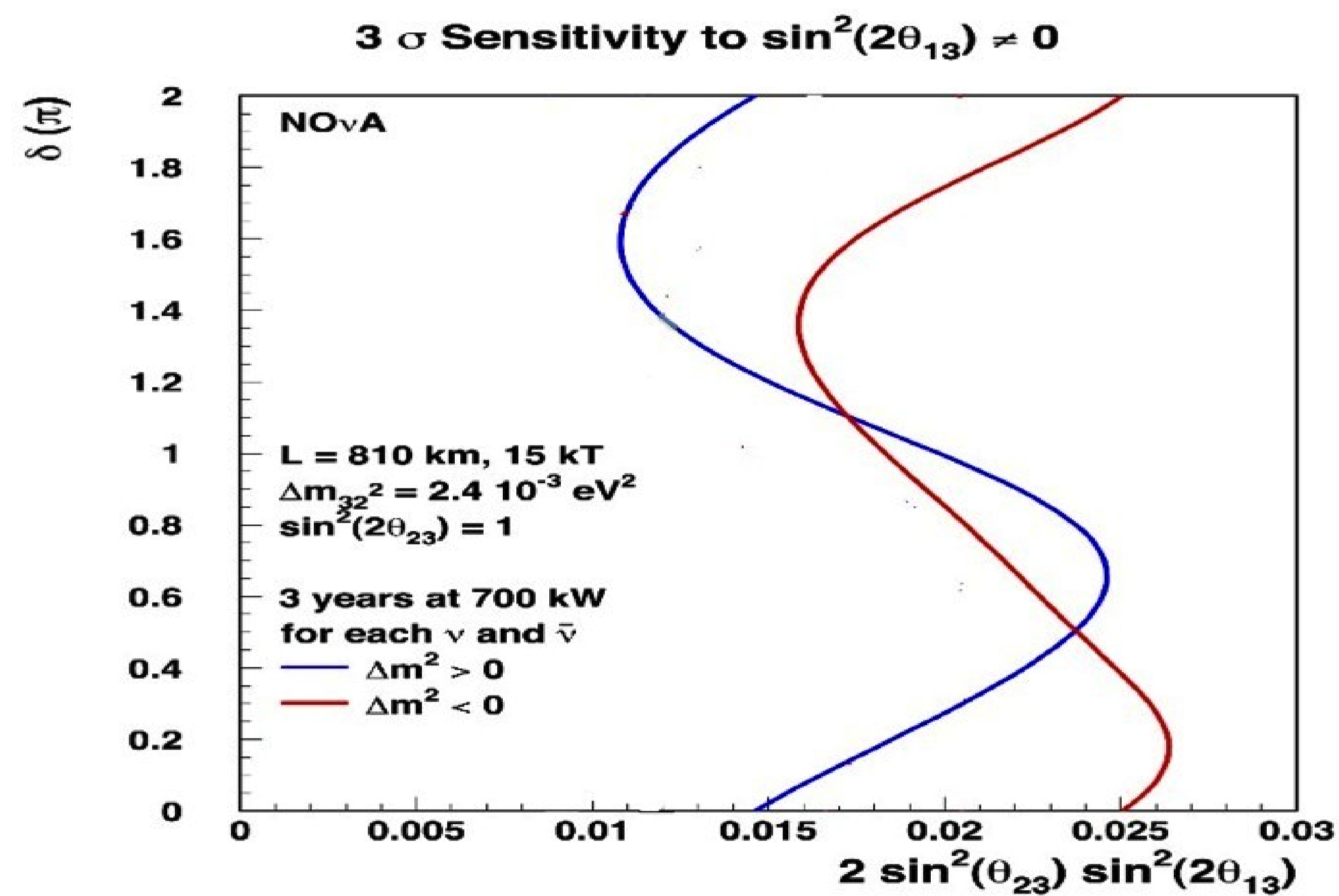
- The NOvA experiment is 800km big!
- It will have two detectors: one located, underground, in the MINOS hall at Fermilab (The Near Detector), the other one located in Ash River, northern Minnesota (The Far Detector).
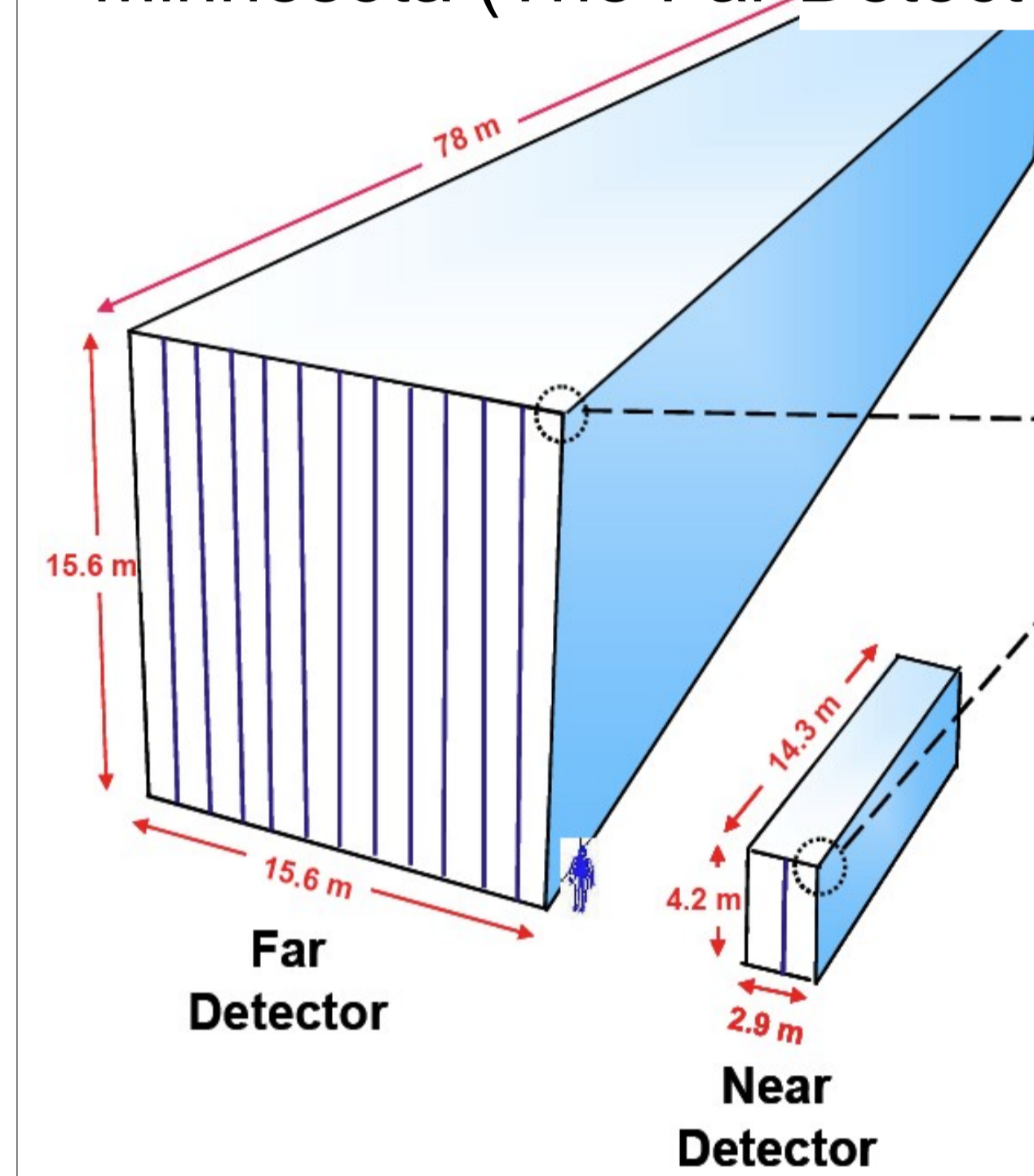

- The detectors are made out of PVC *Modules*.
- They are filled with *Liquid Scintillator*.
- Modules are divided in cells, and each cell has a **Wavelength Shifting Fiber** to collect light.
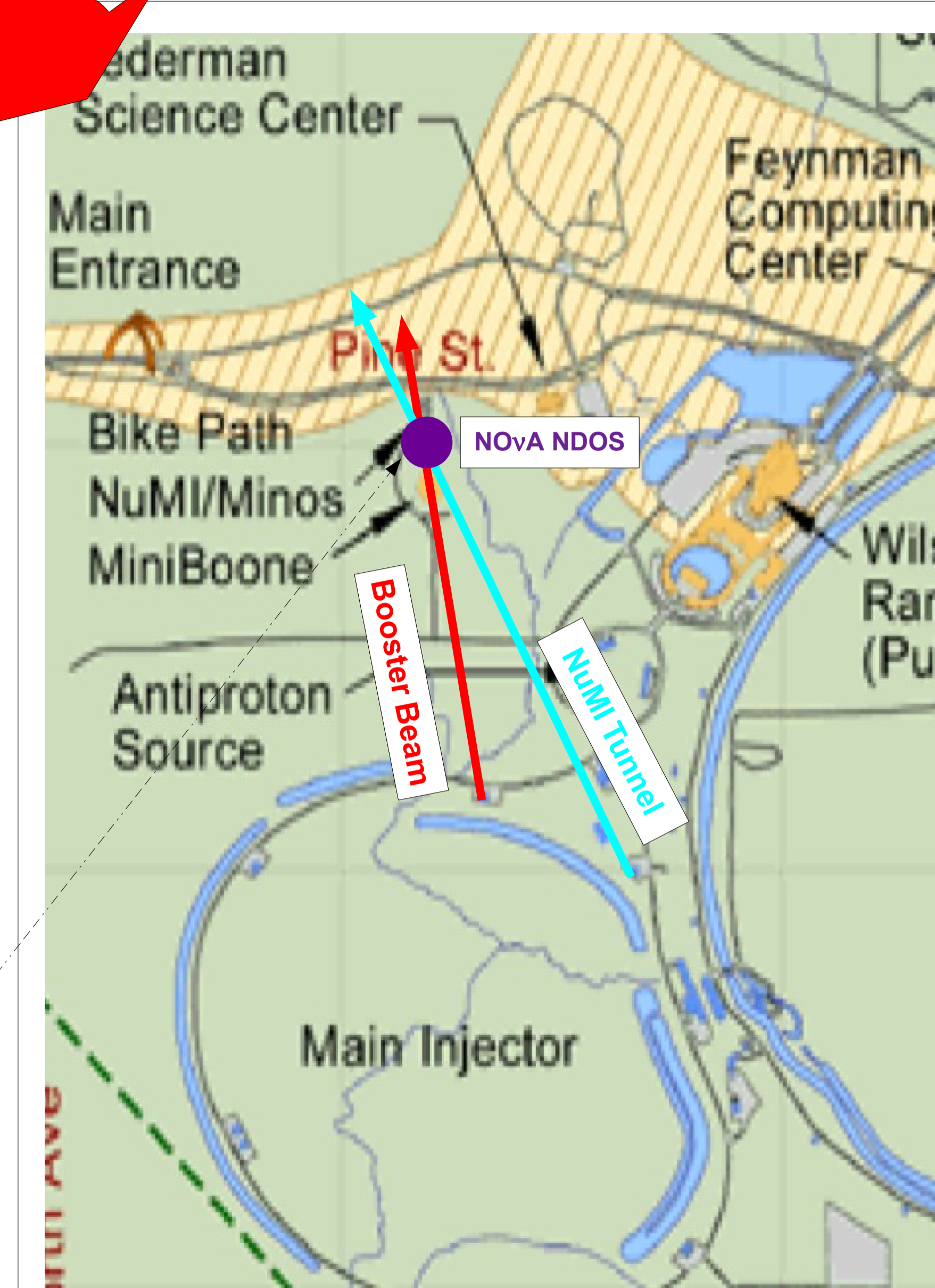
NOvA actually has a third detector: The **NDOS**. However, this one is a prototype that will help the collaboration to gather important information on how to build, calibrate, and operate the other two detectors.

3 σ Sensitivity to $\sin^2(2\theta_{13}) \neq 0$

NOvA
L = 810 km, 15 kT
$\Delta m_{32}^2 = 2.4 \; 10^{-3} \; eV^2$
$\sin^2(2\theta_{23}) = 1$
3 years at 700 kW for each ν and $\bar{\nu}$
— $\Delta m^2 > 0$
— $\Delta m^2 < 0$

x-axis: $2 \sin^2(2\theta_{23}) \sin^2(2\theta_{13})$
y-axis: $\delta (\pi)$

- The sensitivity for measuring θ_{13} depends on δ and Δm^2.
- After 3 years running in neutrino and antineutrino modes, NOvA will set a very low limit on θ_{13}. If this parameter is not too close to zero (or zero), the experiment will be able to measure it!
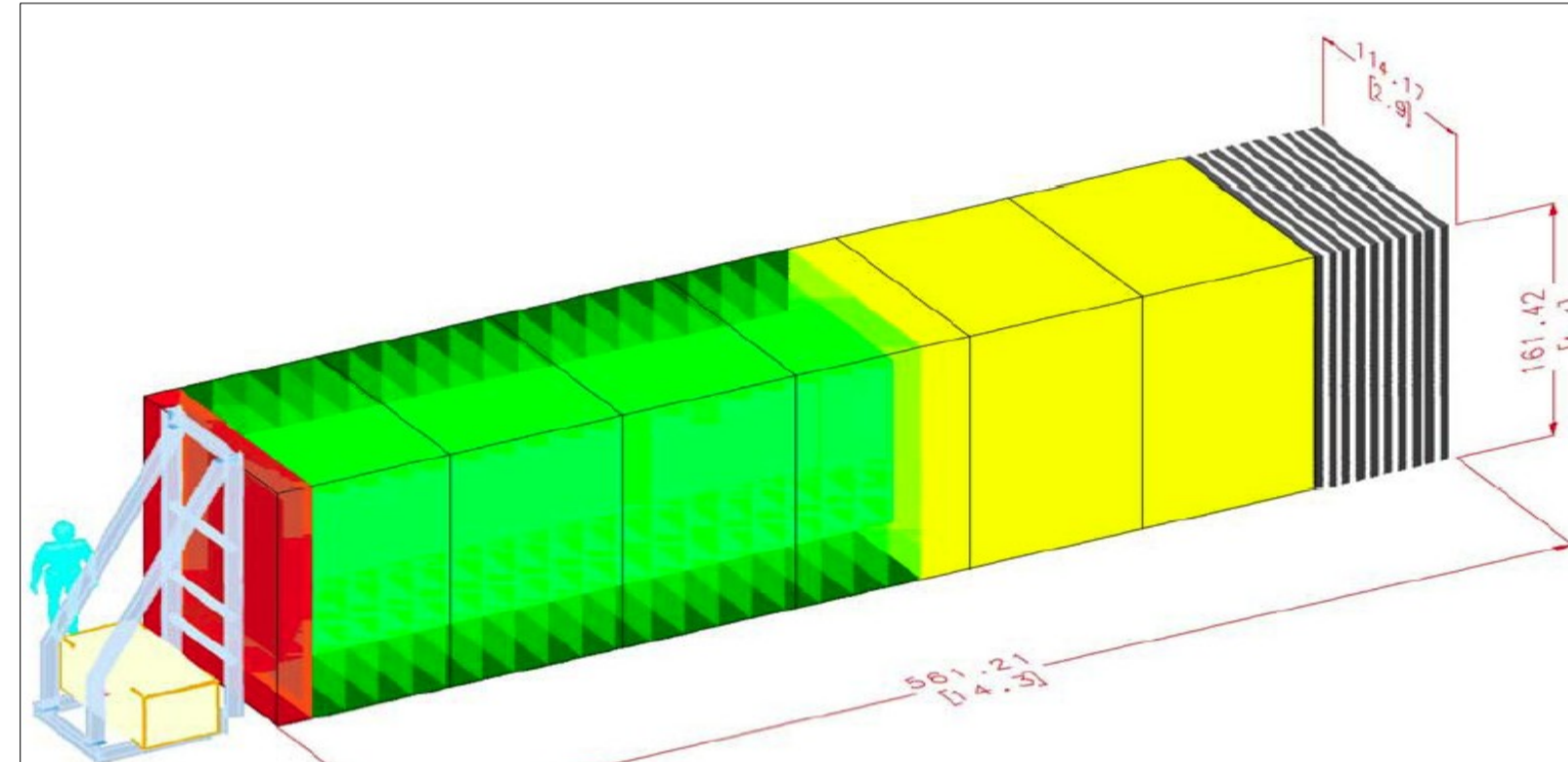
- The *NDOS* is located on the surface between the MINOS and MiniBoone experiments. It is 14m long, 3m wide, and 4m tall.
- The collaboration is commissioning the *NDOS*, and in the mean time is also taking data from two beams:
  - The Booster Beam: 8 GeV protons. On axis.
  - The NuMI Beam: 120 GeV protons. 6° Off axis.

R. Hahn, Fermilab Visual Media Services.
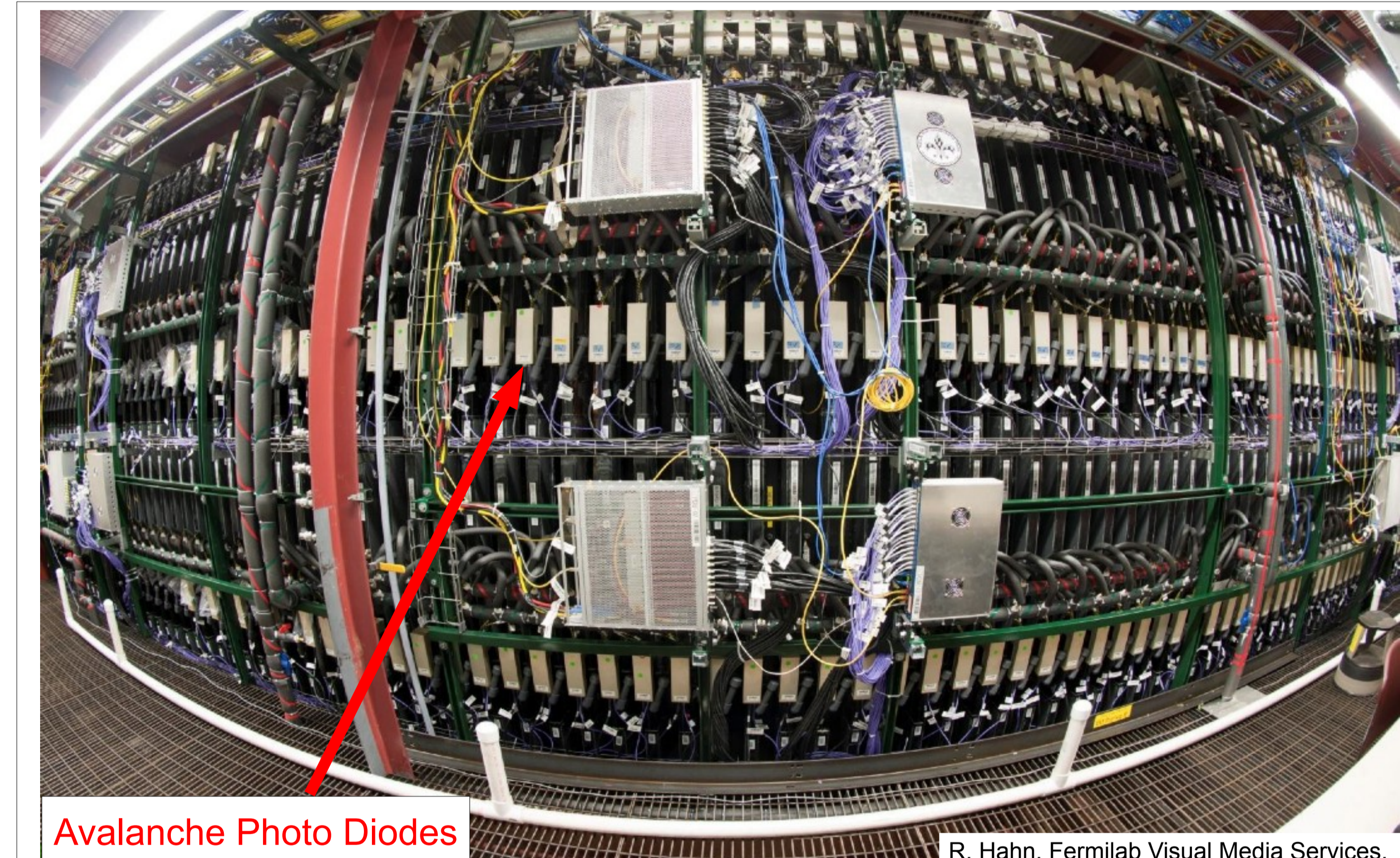
Avalanche Photo Diodes
R. Hahn, Fermilab Visual Media Services.

- With the *NDOS* installation the collaboration will learn about:
  - Data Acquisition Systems.
  - Electronics installation and operation.
  - Energy calibration and light yield.
  - Techniques to fill the modules with oil+scintillator.
  - Assembling the modules.

Time Distribution
Reconstructed μ angle
— Data
— Cosmic Background Data

Neutrino mode: 5.6×10^{18} POT.
253 NuMI events, 39 cosmic BG.
Antineutrino mode: 8.4×10^{19} POT.
1001 NuMI events, 69 cosmic BG.

Time Distribution
Reconstructed μ angle
— Data
— Cosmic
Minerba Betancourt, University of Minnesota.

NuMI neutrino and antineutrino modes
Chad Johnson, Indiana University.

3.05×10^{19} protons on target.
222 Booster events, 92 cosmic background.

ν_μ CC Candidate

NOvA - FNAL E929
Run: 11993/9
Event: 449655
UTC Fri Apr 15, 2011
11:13:34.936636912
Evan Niner, Indiana University.
Zukai Wang, University of Virginia.

Muon

2.15 GeV ν_μ charged current interaction

Beam Direction

Monte Carlo

NOvA - FNAL E929
Run: 1/1
Event: 1
UTC Fri Jan 1, 1970
00:00:0.005000000

Cosmics
Gavin Davies, Iowa State University.

- **NOvA, with the NDOS, has already observed events from:**
  - **The Booster beam.**
  - **The NuMI beam.**
  - **Cosmic rays.**

Dec. 15, 2010
NDOS first neutrino event.

- **NOvA, with the NDOS, has already identified events with:**
  - **Charged current.**
  - **Neutral current.**
  - **Michel electrons.**

Minerba Betancourt, University of Minnesota.